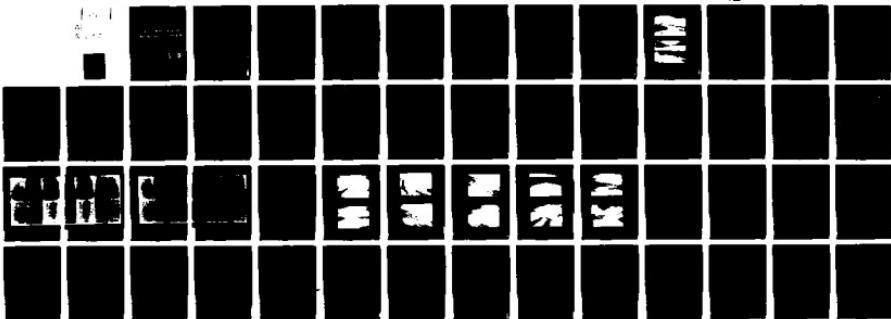


AD-A103 722 ARMY ENGINEER DISTRICT NORFOLK VA
NATIONAL DAM SAFETY PROGRAM. HIDDEN VALLEY LAKE (INVENTORY NUMB--ETC(U)
FEB 81 B S TARAN

F/G 13/13

UNCLASSIFIED

NL



END
DATE FILMED
0 81
DTIG

TENNESSEE RIVER BASIN
LEVEL 1 ✓ *PS*

Name Of Dam: HIDDEN VALLEY LAKE
Location: WASHINGTON COUNTY
Inventory Number: VA 19104 ✓

AD A103722 PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



DTIC ELECTED
SEP 3 1981
S D

A

This document has been approved
for public release and sale; its
distribution is unlimited.

PREPARED BY

NORFOLK DISTRICT CORPS OF ENGINEERS
803 FRONT STREET
NORFOLK, VIRGINIA 23510

DTIC FILE COPY

FEBRUARY 1981

81 9 02 029

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NO' BER VA 19104	2. GOVT ACCESSION NO. <i>AD-A103</i>	3. RECIPIENT'S CATALOG NUMBER <i>722</i>
4. TITLE (and subtitle) Phase I Inspection Report National Dam Safety Program Hidden Valley Lake Washington County, VA		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) <u>Norfolk District, Boris O. Taran</u>		8. CONTRACT OR GRANT NUMBER(s) <u>Norfolk District</u>
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer District, Norfolk 803 Front Street Norfolk, Virginia 23510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE February 1981
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are obtainable from National Technical Information Service, Springfield, Virginia 22151		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Dams - VA National Dam Safety Program Phase I Dam Safety Dam Inspection		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (See reverse side)		

20. Abstract

Pursuant to Public Law 92-367, Phase I Inspection Reports are prepared under guidance contained in the recommended guidelines for safety inspection of dams, published by the Office of Chief of Engineers, Washington, D. C. 20314. The purpose of a Phase I Inspection is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general conditions of the dam is based upon available data and visual inspection. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

Based upon the field conditions at the time of the field inspection and all available engineering data, the Phase I report addresses the hydraulic, hydrologic, geologic, geotechnic, and structural aspects of the dam. The engineering techniques employed give a reasonably accurate assessment of the conditions of the dam. It should be realized that certain engineering aspects cannot be fully analyzed during a Phase I inspection. Assessment and remedial measures in the report include the requirements of additional indepth study when necessary.

Phase I reports include project information of the dam appurtenances, all existing engineering data, operational procedures, hydraulic/hydrologic data of the watershed, dam stability, visual inspection report and an assessment including required remedial measures.

TENNESSEE RIVER BASIN

9
6
National Dam Safety Program. Hidden
Valley Lake (Inventory Number VA 19104)
Tennessee River Basin, Washington County,
Virginia. Phase I Inspection Report.

9 Final Rep't 2/1
NAME OF DAM: HIDDEN VALLEY LAKE
LOCATION: WASHINGTON COUNTY, VIRGINIA
INVENTORY NUMBER: VA 19104

10
PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Prepared by
NORFOLK DISTRICT CORPS OF ENGINEERS
803 FRONT STREET
NORFOLK, VIRGINIA 23510

FEBRUARY 1981

This document has been approved
for public release and sale; its
distribution is unlimited.

411434

JP

TABLE OF CONTENTS

Preface	i
Brief Assessment of Dam	ii
Overview of Dam	
Section 1: PROJECT INFORMATION	1-1
Section 2: ENGINEERING DATA	2-1
Section 3: VISUAL INSPECTION	3-1
Section 4: OPERATIONAL PROCEDURES	4-1
Section 5: HYDRAULIC/HYDROLOGIC DATA	5-1
Section 6: DAM STABILITY	6-1
Section 7: ASSESSMENT/REMEDIAL MEASURES	7-1
Appendix I: Maps and Drawings	
Appendix II: Photographs	
Appendix III: Field Observations	
Appendix IV: Previous Inspection Report	
Appendix V: References	

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established guidelines, the spillway design flood is based on the estimated "Probable Maximum Flood" for the region (flood discharges that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the design flood should not be interpreted as necessarily posing a highly inadequate condition. The design flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

BRIEF ASSESSMENT OF DAM

Name of Dam: Hidden Valley Lake
State: Virginia
Location: Washington County
USGS Quad Sheet: Brumley Virginia
Stream: Brumley Creek
Date of Inspection: 25 February 1981

Hidden Valley Lake Dam is an earthfill embankment structure about 560 feet long and 32.3 feet high. The dam is owned and maintained by the Virginia Commission of Game and Inland Fisheries. The dam is classified as an intermediate size dam with a significant hazard classification. The principal spillway is a concrete drop-inlet riser, and the emergency spillway is an open channel in the right abutment. The dam is used for recreation.

Based on criteria established by the Department of the Army, Office of the Chief of Engineers (OCE), the Spillway Design Flood (SDF) is the 1/2 PMF. The spillways will pass 39 percent of the PMF or 78 percent of the SDF without overtopping the dam. The SDF will overtop the dam by 1.11 feet, reach an average critical velocity of 4.8 feet per second (fps) and flow over the dam for 2.5 hours. Flows overtopping the dam during the SDF are not considered detrimental to the structure. The spillways are adjudged as inadequate, but not seriously inadequate.

The visual inspection revealed no apparent problems and there are no immediate needs for remedial measures. Maintenance is performed by the owners. However, there is no regular maintenance operations plan or warning system. A previous inspection report noted a possible piping problem on the upstream slope. There are no records indicating the repair or correction of this condition. For this reason it is recommended that the services of a qualified geotechnical engineering firm be engaged to determine the condition of the upstream slope and perform a stability check of the dam. This should be completed within 12 months. It is also recommended that a regular maintenance and operations program be instituted with provisions for accurate records of all maintenance performed, and that a warning system be established. The maintenance items listed in Section 7.2 should be accomplished as part of the regular maintenance program within the next 12 months.

Submitted By:

Original signed by
JAMES A. WALSH

JAMES A. WALSH, P. E.
Chief, Design Branch

Recommended By

ORIGINAL SIGNED BY
CHARLES C. HALLER

for JACK G. STARR
Chief, Engineering Division

Approved:

Original signed by:
Douglas L. Haller

DOUGLAS L. HALLER
Colonel Corps of Engineers
District Engineer

Date: MAY 20 1981



DAM



RESERVOIR AREA

**OVERALL VIEWS
HIDDEN VALLEY LAKE DAM**

25 FEBRUARY 1981

SECTION 1
PROJECT INFORMATION

1.1 GENERAL:

1.1.1 Authority: Public Law 92-367, 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers to initiate a National Program of Safety Inspections of Dams throughout the United States. The Norfolk District has been assigned the responsibility of supervising the inspection of dams in the Commonwealth of Virginia.

1.1.2 Purpose of Inspection: The purpose is to conduct a Phase I inspection according to the Recommended Guidelines for Safety Inspection of Dams (Reference 1, Appendix V). The main responsibility is to expeditiously identify those dams which may be a potential hazard to human life or property.

1.2 Project Description:

1.2.1 Dam and Appurtenances: Hidden Valley Lake Dam is an earthfill structure about 560 feet long and 32.3 feet high. The crest of the dam is 16 feet wide with an average crest elevation of 3607.0 feet m.s.l. The upstream slope is 3 horizontal to 1 vertical (3H:1V) from elevation 3607 to elevation 3604.5, (1.5H:1V) from elevation 3604.5 to elevation 3600.5 with riprap protection, and (3H:1V) below elevation 3600.5. An earth berm is located at the waterline, elevation 3600.5. The downstream slope is 2.5H:1V. It is unknown if the dam is keyed into the foundation or whether or not there is a drainage system. There are no foundation drain outlets.

The principal spillway is a concrete drop-inlet riser located in the reservoir. Six 7.5-inch high flashboards are stacked horizontally below the crest of the riser. The flashboards can be removed to allow flow downstream of the dam. A 12-inch cast iron pipe, placed vertically on the upstream side of the riser, acts as a siphon when the reservoir is at normal pool (elevation 3600.5). The siphon allows for continuous drawoff and withdrawal of low oxygen water. Flows into the riser pass through the dam in a 30-inch reinforced concrete pipe and discharge onto a concrete slab in a rock lined stilling basin.

The emergency spillway is an open channel spillway cut into natural rock at the right abutment. The crest of the emergency spillway is about 37 feet wide with a crest elevation of 3602.0.

The reservoir can be drained by operating an 18-inch square gate with invert, elevation 3576.2, located at the base of the intake riser.

1.2.2 Location: Hidden Valley Lake Dam is located about 3 miles northwest of Brumley Gap, Virginia in the Jefferson National Forest.

1.2.3 Size Classification: The dam is classified as an intermediate size dam, because of the maximum storage potential as defined in Reference 1 of Appendix V.

1.2.4 Hazard Classification: The Hidden Valley Lake Dam is located 3 to 4 miles upstream of several structures located along Brumley Creek. During a dam failure people living in or near these structures would be in danger of losing their property and possibly their lives. Therefore, a significant hazard classification is given for this structure according to guidelines contained in Section 2.1.2 of Reference 1 of Appendix V. The hazard classification used to categorize dams is a function of location only and has nothing to do with their stability or probability of failure.

1.2.5 Ownership: Virginia Commission of Game and Inland Fisheries.

1.2.6 Purpose: Recreation.

1.2.7 Design and Construction History: It is not known when the original dam was constructed, but during 1963-64 the dam was raised several feet, extended, and a 24-inch drawdown pipe was replaced with a 30-inch reinforced concrete pipe connecting a new drop-inlet riser. Riprap was placed on the upstream slope between elevations 3600.5 and 3604.5. W. C. Perrow, Consulting Engineer, developed drawings and specifications for the proposed 1962 expansion (See Plates I & II, Appendix I).

1.2.8 Normal Operational Procedures: Water passes automatically through the principal spillway; either, over the concrete crest, through the 12-inch cast iron siphon, or over the top of the partially removed flashboards.

1.3 Pertinent Data:

1.3.1 Drainage Area: The dam controls a drainage area of 1.67 square miles.

1.3.2 Discharge at Dam Site: Maximum flood - unknown.

Pool level at crest of dam

1.3.3 Dam and Reservoir Data: Pertinent data on the dam and reservoir are shown in the following table:

TABLE 1.1 DAM AND RESERVOIR DATA

Item	Elevation feet msl	Reservoir			
		Area, acres	Acre, feet	Capacity Watershed, inches 1/	Length feet
Crest of Dam	3607.0	105	1975	22.2	5600
Emergency Spillway Crest	3602.0	95	1550	17.4	5400
Principal Spillway Crest	3600.5	90	1350	15.2	4400
Streambed at Down- stream Toe of Dam	3574.7	--	--	--	--

SECTION 2

ENGINEERING DATA

2.1 Design: There is no known design information for the original structure. Design drawings (See Plates I & II, Appendix I) and contract specifications are available for the 1963-64 modifications, which include a new intake structure, and flattening of both the upstream and downstream slopes.

2.2 Construction: There are no known construction records. However, the contract specifications for the 1963-64 modifications call for borrow material to be taken from a site approximately 400 feet northeast of the dam. The material was to be placed in 6-inch lifts and compacted with a sheepsfoot roller having a soil contact pressure of 200 psi, "until 100% of the maximum density at optimum moisture content is obtained".

2.3 Evaluation: There is insufficient information to evaluate the foundation conditions and the embankment stability.

SECTION 3
VISUAL INSPECTION

3.1 Findings:

3.1.1 General: The results of the 25 February 1981 inspection are recorded in Appendix III. At the time of the inspection the weather was clear and cool. The temperature was 35-45°F. and the ground was covered by about 1 inch of snow. The pool elevation was 3600.1 feet m.s.l. or about 0.4 feet below the normal pool elevation. Two boards had been removed from the boarded spillway causing flow through the principal spillway. A prior inspection by Froehling & Robertson, Inc., dated 20 June 1972, (See Appendix IV) revealed several items which required remedial action.

1. Minor erosion on the upstream face.
2. A conical depression on the upstream face approximately 40 feet downstream of the intake structure (the reservoir was drained at the time of the inspection).
3. A road cut into the downstream face of the dam.
4. A large animal burrow along the principal spillway outlet pipe (Exact location not specified).
5. Leaks (10 feet of water in reservoir) in the principal spillway outlet pipe at the junction between the pipe and the tower and approximately 49 feet downstream of the tower (about the same location as the conical depression, See No. 2).

Recommendations were to place additional riprap on the upstream face, fill the road on the downstream slope, fill the animal burrow, and repair the leaks of the principal spillway outlet pipe.

Also noted in the report was a design drawing dated 7 February 1964 for field repairs of a shear crack in the first section of the outlet pipe from the intake tower. Repairs were to be made on both the inside and the outside of the pipe section (the drawing is not available). The inspection revealed that repairs were made on the inside but could not ascertain whether the outside repairs were made or if there was any leakage through the old crack.

3.1.2 Embankment: The embankment is in fair condition. A sketch showing a plan view at the time of inspection is included at the back of the checklist in Appendix III. Available design drawings are also included in Appendix I. An overall view of the dam is provided at the beginning of the report.

There are no signs of surface cracks, unusual movement, or misalignment. However, a roadway has been cut into the downstream face of the embankment beginning at the crest and running down the left abutment to a point just above the outfall pipe. The right slope of the road cut is bare. Also, a foot path runs down the downstream face

from the crest to the outfall pipe and several tire ruts are located on the crest, which serves as a gravel and dirt road (See Sketch, Appendix III and Photo Nos. 1, 4, and 5, Appendix II).

The full length of the upstream face is riprapped from approximately 2 feet below the crest to the bench. Riprap failures are located at Stations 2+05, 2+36, 3+08 to 3+45, 4+18 and 4+66. Between Stations 4+75 and 5+85, the riprap is small and ravelling is prevalent (See Overall View of the Dam at the beginning of report, Photo Nos. 2 and 6, Appendix II, and Sketch, Appendix III).

A wet area exists along the toe of the downstream left abutment beginning at approximately Station 5+20. The area is about 25 feet wide and extends to about Station 3+80 where it is about 8 feet wide. At this point, a small eroded ditch carries the water into the stilling basin (See Sketch, Appendix III).

A small stream runs down the left slope of the downstream valley approximately 50 feet from the toe. It disappears into the ground at approximately Station 4+00 (See Sketch, Appendix III).

A wet area also exist on the downstream right abutment beginning at approximately Station 1+50 extending 15 feet out from the toe and down the abutment to the outfall pipe (See Sketch, Appendix III).

There are no known embankment drains.

Area soils are low plastic sandy silts and sandy clays.

The embankment is well vegetated with grass, except the riprapped portion of the upstream face and the road traversing the crest. Small saplings and shrubs are scattered on the downstream face (See Photos No. 1 through 5, Appendix II).

3.1.3 Principal Spillway: The concrete drop inlet is in good condition. Two of the six 7.5-inch flashboards have been removed to allow flow through the spillway. The representative for Virginia Commission of Game and Inland Fisheries (VCGIF) reports that the reservoir has been drained 3 times in the last 7 years. The outlet pipe passes under the dam and discharges onto a splash block at the downstream toe. A flow of approximately 10 inches deep is passing through the pipe. (See Plate I, Appendix I and Photo Nos. 7 and 8, Appendix II).

3.1.4 Emergency Spillway: The emergency spillway is an earth and rock channel on natural ground around the right abutment of the dam. A concrete driveway from the crest of the dam to the bottom of the channel forms the left slope of the control section. Natural rock outcrops are located throughout the area and form the bottom and right slope of the control section. The approach channel is sparsely vegetated and slightly sloped in natural ground. The discharge channel directs flows parallel to the downstream channel and drops about 50 feet in elevation, sharply, approximately 1000 feet downstream of the control section. A large erosion

gully, 8-10 feet deep, is located at this point (See Plate I, Appendix I, Photo Nos. 9 and 10, Appendix II and Sketch, Appendix III).

3.1.5 Instrumentation: There is no instrumentation on the dam.

3.1.6 Reservoir Area: The reservoir slopes are mild to steep and heavily wooded. The watershed has no development or cleared areas. The lake is covered with a thick layer of ice, except around the shoreline. There is no evidence of shoreline erosion or reservoir slope failure. The inspection team was unable to evaluate the sedimentation condition. An overall view of the reservoir area is provided at the beginning of the report.

3.1.7 Downstream Channel: The downstream channel is cluttered with large boulders and some trees near the stream. The channel drops rapidly in elevation so there should not be a problem with obstructed flows. The slopes are very steep and heavily wooded. Structures are located along the stream about 4-5 miles downstream of the dam.

3.2 Evaluation: The previous inspection report noted five items requiring remedial action, which should have been accomplished prior to this inspection. The reported conical depression on the upstream face is below the water level in the reservoir and cannot be checked. There is no access to the intake structure; therefore, the leaks in the outlet pipe cannot be checked. There are no records available to indicate that either of these two items have been remedied. Of the remaining three, the animal burrow was not found, minor erosion still exist on the upstream face, and the road down the downstream face has not been backfilled.

Based on this visual inspection, the dam is in good overall condition. However, several preventative maintenance items were noted, which should be scheduled as part of an annual maintenance program. These are:

- a. The roadway on the downstream face should be filled with compacted material to the existing slope of the dam and be seeded.
- b. The tire ruts on the crest should be filled with compacted material and an additional 1 to 2 inches of gravel should be placed on the road.
- c. The logs floating at the upstream face should be removed.
- d. The riprap failures should be repaired and additional riprap placed in areas of minor erosion (ravelling).
- e. All wet areas and streams should be monitored for an increase in flow during periodic inspections.
- f. A paved channel or half pipe sections should be provided to prevent erosion from the flow from the wet area on the left abutment.

- g. The shrubs and saplings on the embankment should be cut off at ground level.
 - h. A staffgage should be installed in the reservoir to extend above the crest of the dam.

SECTION 4

OPERATIONAL PROCEDURES

4.1 Procedures: The normal storage pool is elevation 3600.5 ft. msl, which is the crest of the principal spillway drop-inlet. The reservoir provides recreation. Water passes automatically into the drop-inlet either by flowing over the crest of the drop inlet, passing through the slot of a removed flashboard or through the 12-inch cast iron pipe acting as a siphon during normal pool. The flows then pass through a 30-inch reinforced concrete pipe running through the dam at low level. When the reservoir rises above elevation 3602.0, water automatically flows through the emergency spillway. An 18-inch square gate, located at the bottom of the drop-inlet, can be used to drain the reservoir.

4.2 Maintenance: The Virginia Commission of Game and Inland Fisheries performs maintenances on an as-needed basis.

4.3 Warning System: At present time, there is no warning system or evacuation plan for Hidden Valley Lake Dam.

4.4 Evaluation: The dam does not require an elaborate operational and maintenance procedure. However, a regular maintenance program should be initiated and documented to help detect and correct problems as they occur. An emergency operation and warning plan should be developed. It is recommended that formal emergency procedure be prepared and furnished to all operating personnel. This should include:

- a. How to operate the dam during an emergency.
- b. Who to notify, including public officials, in case evacuation from the downstream area is necessary.

SECTION 5

HYDRAULIC/HYDROLOGIC DATA

- 5.1 Design: None were available.
- 5.2 Hydrologic Records: None were available.
- 5.3 Flood Experience: The maximum flow at the dam site is unknown.
- 5.4 Flood Potential: The 100-year flood, 1/2 PMF, and PMF were developed and routed through the reservoir by use of the HEC-1DB computer program (Reference 2, Appendix V) and appropriate unit hydrograph, precipitation and storage-outflow data. Clark's Tc and R coefficient for the local drainage area were estimated from basin characteristics. The rainfall applied to the developed unit hydrograph was obtained from the U. S. Weather Bureau Publication (Reference 3, Appendix V).
- 5.5 Reservoir Regulation: Pertinent dam and reservoir data are shown in Table 1.1.
- Water passes automatically through the dam as the reservoir rises above the principal spillway crest.
- The storage curve was developed based on areas obtained from a U. S. Geological Survey Quadrangle Map. Rating curves for the principal spillway, emergency spillway, non-overflow section and drawdown were developed. In routing hydrographs through the reservoir, it was assumed that the initial pool level was at the principal spillway crest (elevation 3600.5).
- 5.6 Overtopping Potential: The probable rise in the reservoir and other pertinent information on reservoir performance is shown in the following table:

Table 5.1 RESERVOIR PERFORMANCE

Item	Normal Flow	100 1/ Year	1/2 PMF	PMF 2/
Peak flow c.f.s.				
Inflow	2	2565	8110	16221
Outflow	2	216	3580	13465
Maximum elevation ft. msl	3600.5	3602.5	3608.1	3610.8 3610.6
Non-overflow section (el 3235 ft msl)	3607	-	-	-
Depth of flow, ft	-	-	1.1	3.6
Duration, hrs	-	-	2.5	4.8
Velocity, fps 3/	-	-	4.8	8.7
Tailwater elevation ft msl	3573.9+	-	-	-

1/ The 100-Year Flood has one chance in 100 of occurring in any given year.

2/ The PMF is an estimate of flood discharges that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

3/ Critical Velocity

3576.2

5.7 Reservoir Emptying Potential: An 18-inch square gate with invert elevation at 3575.2 is available for dewatering the reservoir. The low level outlet will permit a withdrawal of about 51 cfs with the reservoir level at the crest of the principal spillway and essentially dewater the reservoir in 26 days without removing the flashboards. This is equivalent to an approximate drawdown rate of 1.1 feet per day. This is based on the hydraulic head measured from the maximum storage pool at elevation 3600.5 to elevation 3576.2 divided by the time to dewater the reservoir.

5.8 Evaluation: Hidden Valley Lake Dam is an intermediate size dam with a significant hazard classification requiring evaluation for a spillway design flood in the range between the 1/2 PMF and PMF. Due to the risk involved, the 1/2 PMF has been selected as the SDF. The spillways will pass 39 percent of the PMF or 78 percent of the SDF without overtopping the crest of the dam. The SDF was routed through the reservoir and found to overtop the dam by 1.1 feet, reach an average critical velocity of 4.8 fps and flow over the dam for 2.5 hours.

Conclusions pertain to present day conditions and the effect of future development on the hydrology has not been considered.

SECTION 6

DAM STABILITY

6.1 Foundation and Abutments: There is no information available on the foundation conditions. The dam is located in the Ridge and Valley Physiographic Province of Southwestern Virginia and is underlain by Silurian clastic rocks of the Clinch-Tuscarora and Clinton Formations. These formations consist of white, red, and grey shale, sandstones and quartzites. Sandstone outcrops are predominate on both abutments. These rocks should provide an adequate foundation for the dam provided that adequate care was taken during construction to locate and remove any soft spots which may have been caused by weathering of shale layers. As noted in the visual inspection, there are wet areas on both downstream abutments. It is unknown if the dam is keyed into the foundation or if there are any foundation drains. There are no foundation drain outlets. The predominate exposed foundation materials are relatively impervious, stable, fine grained alluvial soils. The wet spots are probably due to the lack of a toe drainage system and are common under these conditions.

6.2 EMBANKMENT:

6.2.1 Materials: There is no information available on the nature of the materials. The area soils are low plastic sandy silts and sandy clays.

6.2.2 Stability: There are no available stability calculations. The dam is 32.3 feet high and 16 feet wide. The slopes are 3.0H:1V upstream and 2.5H:1V downstream. The dam is subject to sudden drawdown because the approximate reservoir drawdown rate of 1.1 feet per day exceeds the critical rate of 0.5 feet per day for earth dams. The existing pool is 0.3 feet below normal pool. It is unknown if the dam has ever experienced the maximum control storage pool, which is at the emergency spillway crest (1.4 feet above normal pool).

According to the guidelines presented in Design of Small Dams, U. S. Department of the Interior, Bureau of Reclamation (Reference 5, Appendix V) for small homogenous dams, with a stable foundation subject to a sudden drawdown, the recommended slopes are 3.5H:1V upstream and 2.5H:1V downstream. The recommended crest width is 17 feet. Based on these guidelines, the dam has an adequate downstream slope, but an inadequate upstream slope and crest width.

6.2.3 Seismic Stability: The dam is located in Seismic Zone 2. Therefore, according to the Recommended Guidelines for Safety Inspection of Dams (Reference 1, Appendix V), the dam is considered to have no hazard from earthquakes provided static stability conditions are satisfactory and conventional safety margins exist.

6.3 Evaluation: There is insufficient information to adequately evaluate the stability of the dam. The visual inspection revealed no

apparent instability. Overtopping is not a problem because flows are shallow, last 2.5 hours, and the velocity is less than 6 feet per second, the effective eroding velocity for a vegetated earth embankment. However, the previous inspection report noted a conical depression on the upstream slope approximately over a leak in the principal spillway outlet pipe at about the location of the old intake structure. This indicates the possibility of piping which poses a potentially serious threat to the stability of the embankment. The leak may have been caused by excessive settlement of, or in the improper installation of, the new portion of the outlet pipe. There are no records to indicate that the leak or the depression was repaired. Therefore, it is recommended that the service of a qualified geotechnical engineering firm be engaged to determine the condition of the upstream slope and perform a stability check on the dam. This is necessary because of the lack of records indicating the correction of a potentially serious threat to the embankment stability. This should be completed within 12 months.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment: The available engineering data is insufficient to evaluate the embankment stability. The visual inspection revealed no findings that proved the dam to be unsound. However, the previous inspection report noted a case of possible piping on the upstream slope. There are no records indicating the repair of this condition. There is a limited maintenance program. However, there is no inspection program or emergency operations and warning plan. Based on criteria established by the Department of the Army, Office of the Chief of Engineers (OCE), the Spillway Design Flood (SDF) is the 1/2 PMF. The spillways will pass 39 percent of the PMF or 78 percent of the SDF without overtopping the dam; flows overtopping the dam during the SDF are not considered detrimental to the embankment. The combined capacity of the spillways is adjudged inadequate but not seriously inadequate. Overall the dam appears to be in fair condition and there is no immediate need for remedial measures.

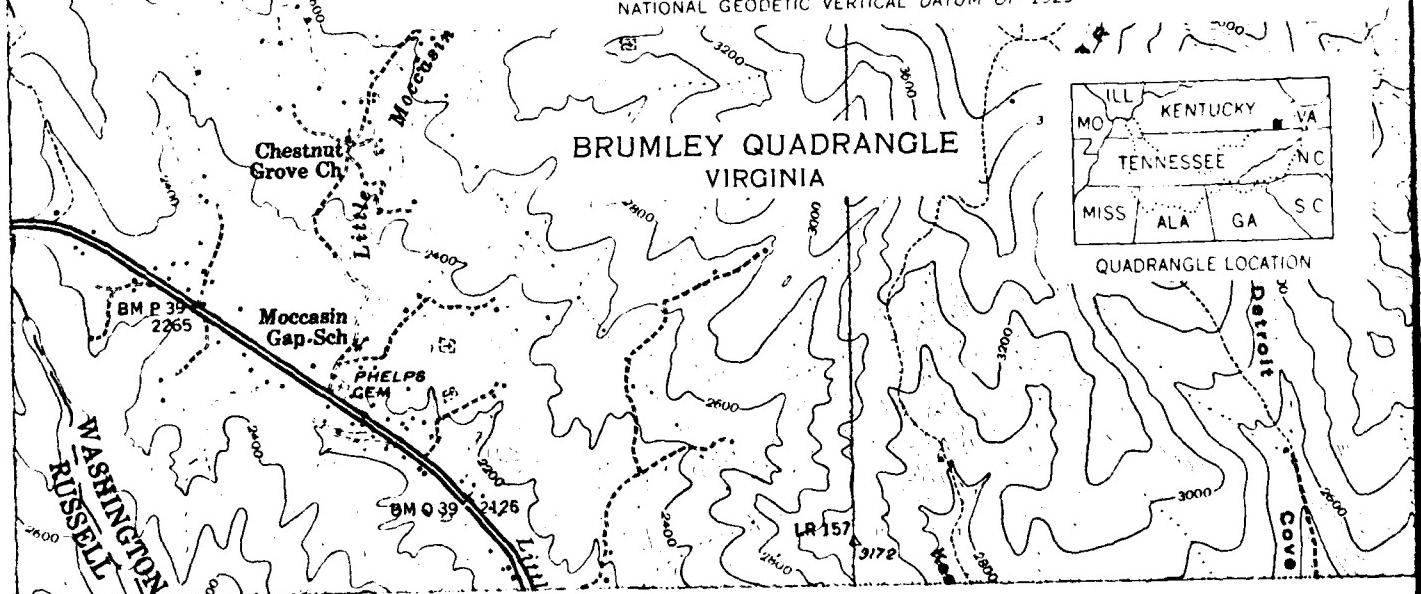
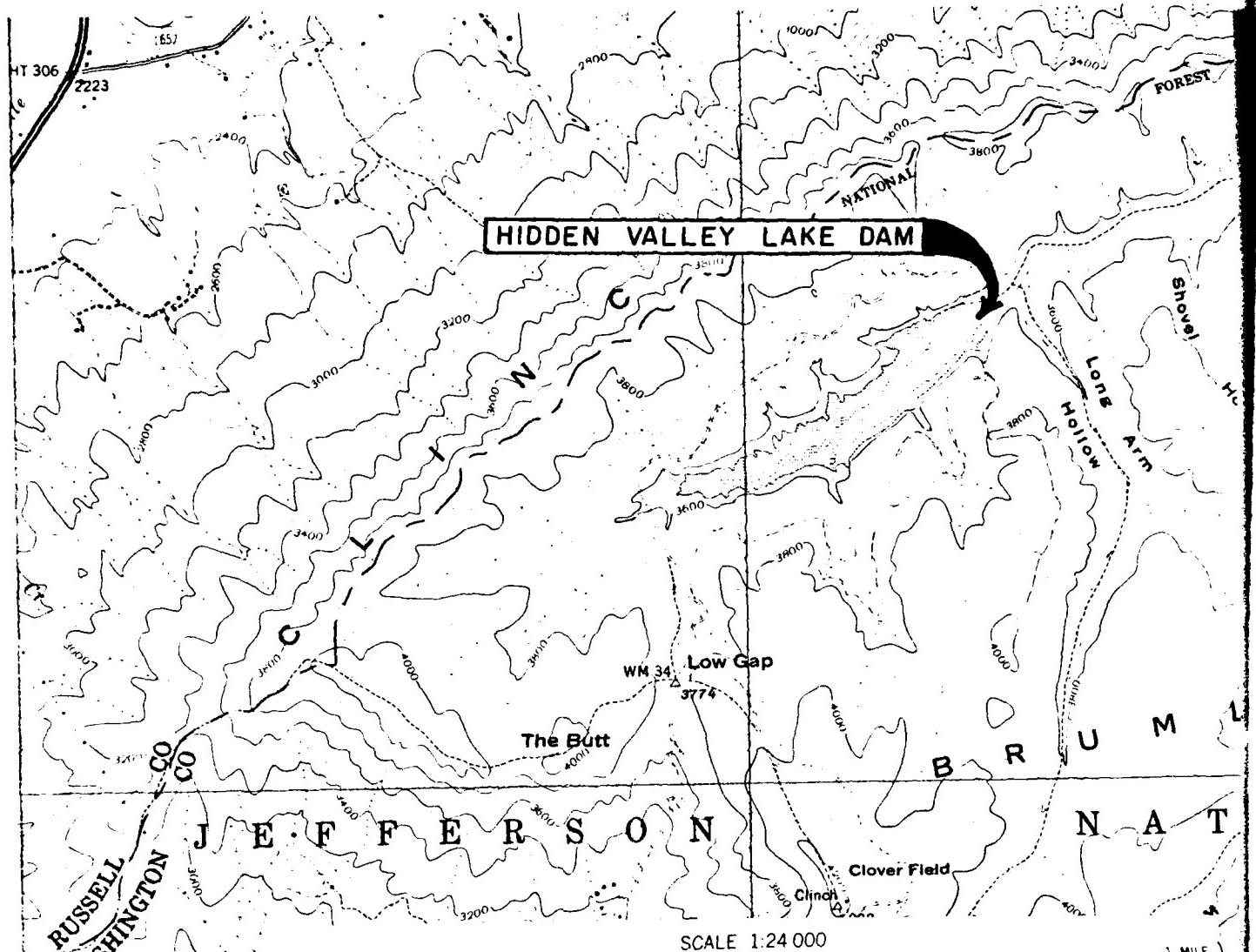
7.2 Recommended Remedial Measures: It is recommended that the services of a qualified geotechnical engineering firm be engaged to determine the condition of the upstream slope and perform a stability check of the dam. This should be completed within 12 months. A regular maintenance and inspection program should be initiated to help detect and control problems as they occur. A formal emergency procedure should be prepared, including how to operate the dam in an emergency and who to notify, including public officials, in case evacuation from the downstream area is necessary. Also, the inspection revealed the following maintenance items that should be scheduled by the owner during a regular maintenance period within the next 12 months:

- a. The roadway on the downstream face should be filled with compacted material to the existing slope of the dam and be seeded.
- b. The tire ruts on the crest should be filled with compacted material and an additional 1 to 2 inches of gravel should be placed on the road.
- c. The logs floating at the upstream face should be removed.
- d. The riprap failures should be repaired and additional riprap placed in areas of minor erosion (ravelling).
- e. All wet areas and streams should be monitored for an increase in flow during periodic inspections.
- f. A paved channel or half pipe sections should be provided to prevent erosion from the flow from the wet area on the left abutment.

g. The shrubs and saplings on the embankment should be cut off at ground level.

h. A staffgage should be installed in the reservoir to extend above the crest of the dam.

APPENDIX I
MAPS AND DRAWINGS



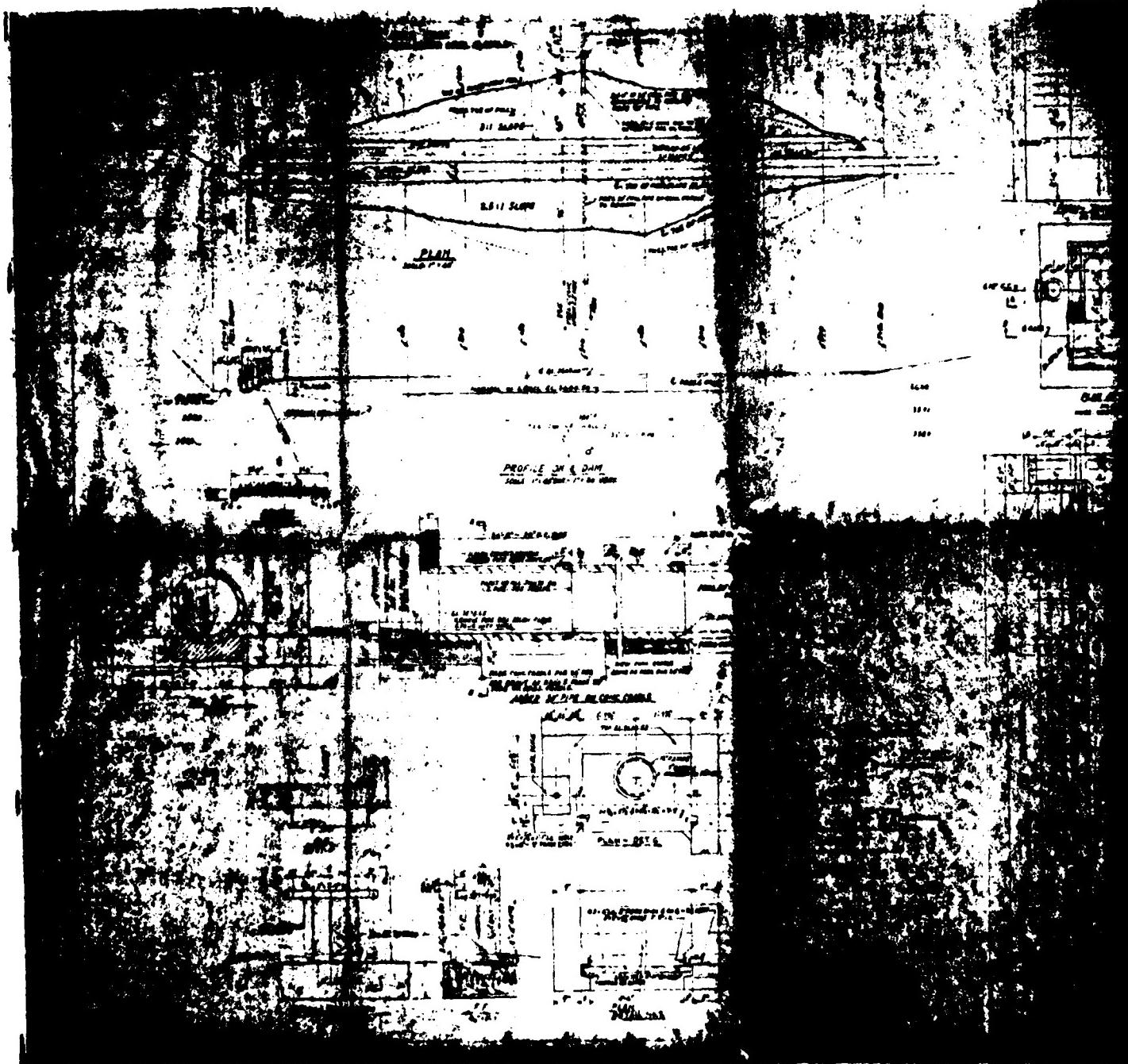
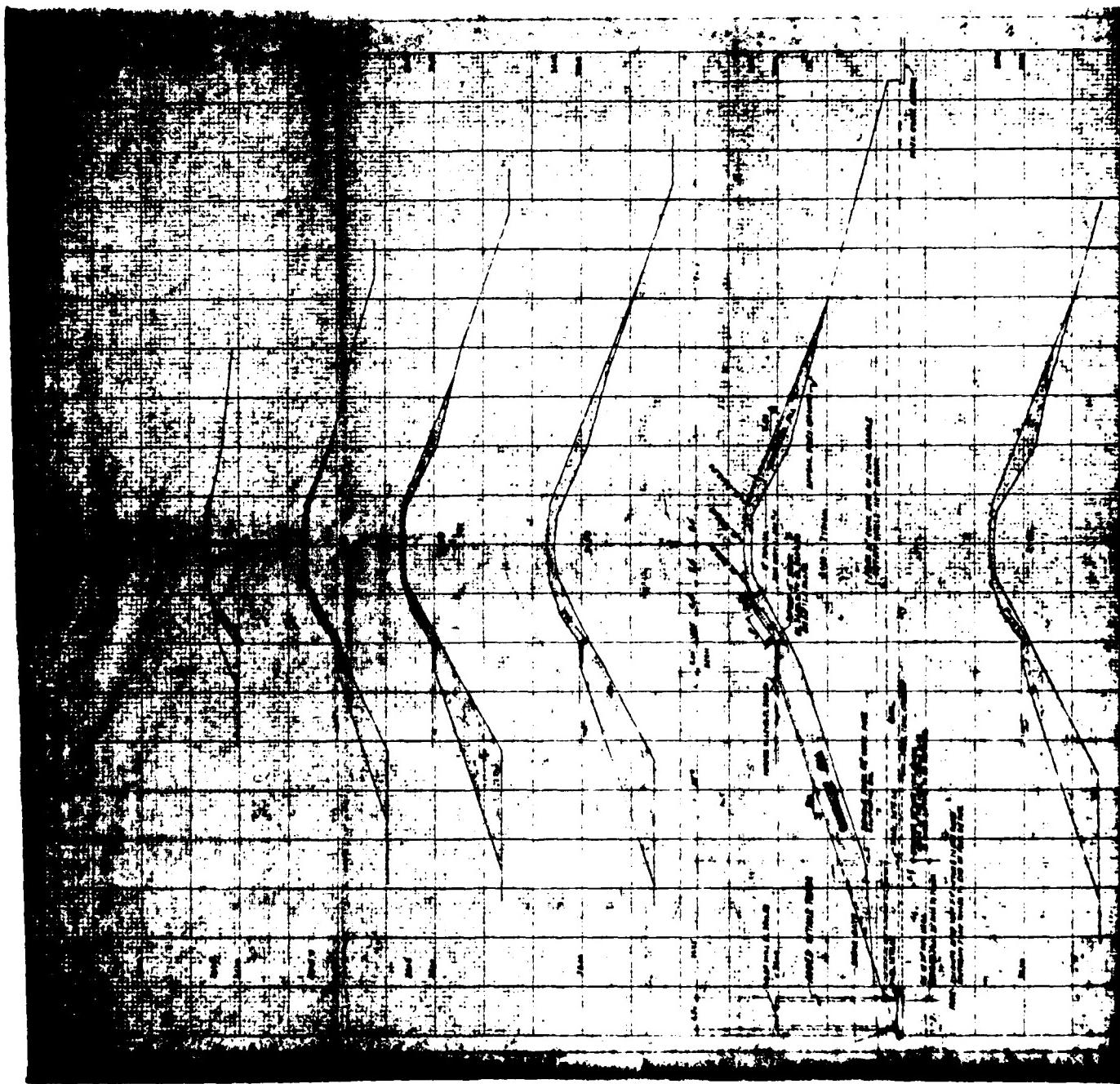


PLATE 1

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

2



SEARCHED INDEXED SERIALIZED FILED

MARSH C. PERIN - CONSULTING ENGINEER	
1000 N. STATE ST., SUITE 1000 PHOENIX, ARIZONA 85004	
DATE	FILED
SEARCHED	INDEXED
SERIALIZED	FILED
MAY 1972	

PLATE II

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDQ

APPENDIX II

PHOTOGRAPHS



PHOTO #1 CREST OF DAM



PHOTO #2 UPSTREAM FACE



PHOTO #3 DOWNSTREAM FACE



PHOTO #4 DOWNSTREAM FACE
(NOTE ACCESS TRAIL
CUT INTO EMBANKMENT)



PHOTO #5 ACCESS TRAIL

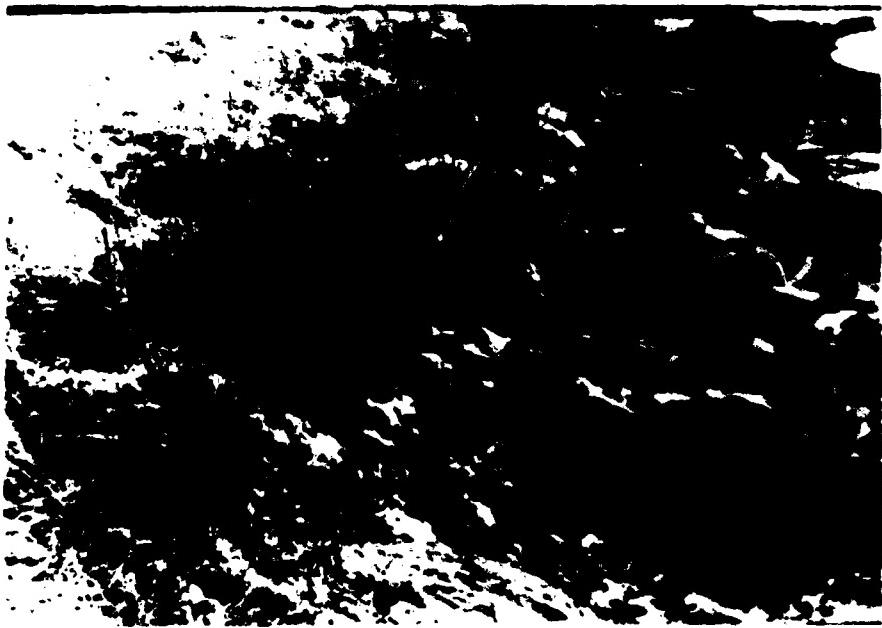


PHOTO #6 LOCALIZED SLOUGHING
RIP-RAP FAILURE
ON U/S FACE



PHOTO #7 PRINCIPAL SPILLWAY
INTAKE STRUCTURE



PHOTO #8 PRINCIPAL SPILLWAY
OUTLET



**PHOTO #9 EMERGENCY SPILLWAY
(EMS) AND CONTACT
LT. ABUTMENT**



PHOTO #10 EMS DISCHARGE CHANNEL

APPENDIX III
FIELD OBSERVATIONS

Check List
Visual Inspection
Phase I

Name Dam: Hidden Valley Lake Dam County: Washington State: Virginia Coordinates: Lat. 30° 51.0' North
Long. 82° 04.4' West

Date Inspection: 25 Feb 1981 Weather: Clear, Cool Temperature: 35° - 45° F

Pool Elevation at Time of Inspection: 3600.1 ft. msl Tailwater at Time of Inspection: 3573.9 ft. msl

Inspection Personnel:

J. Robinson, COE
B. Tarhan, COE
D. Davis, COE

L. Jones, COE
H. Gildea, SWCB
R. Sexton, SWCB

G. Martel, VCGIF

Davis & Robinson, Recorders

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	There are no surface cracks. Ground conditions are moist. (Snow cover of approximately 1 inch).	None.
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	There are no creep, sloughing, or bearing capacity problems.	None.
SLoughing OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	A narrow roadway has been cut into the downstream face of the embankment beginning at the crest and running down the left abutment to a point just above the outfall pipe. The right slope of the road cut is bare. A footpath runs down the downstream face from the crest to the outfall pipe. Several tire ruts are located on the crest of the dam. Several large logs are located at the waters edge on the upstream face near the left abutment.	The roadway should be filled with compacted material to the existing slope of the dam and seeded. The tire ruts should be filled with compacted material. The logs should be removed.
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	The crest serves as a gravel and dirt road and the alignment is straight. There is no noticeable settlement. The conduit alignment appears straight.	An additional 1 to 2 inches of gravel should be placed on the road to prevent further rutting.

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
RIPRAP FAILURES	The full length of the upstream face of the dam is riprapped from approximately 2 feet below the crest to the bench, which is just below the present water level. Riprap failures are located at stations 2+05, 2+36, 3+08 to 3+45, 4+18, and 4+66. Between stations 4+75 and 5+85, the riprap is small and raveling is prevalent.	Riprap should be repaired. (Station numbers refer to Field Sketch).
FOUNDATION	There is no noticeable sliding or settlement. The dam is founded on the sandstone substrata which appears stable; however, its permeability is unknown. Sandstone outcrops are prominent on both abutments. There are no known foundation drains. There is no evidence to suggest that the foundation is unstable.	None.
ANY NOTICEABLE SEEPAGE	A wet area exist at the toe of the downstream left abutment beginning at approximately station 5+20. The area is about 25 feet wide and extends down the left abutment to about station 3+80 where it is eight feet wide. At this point, a small eroded ditch carries the water into the stilling basin.	All wet areas and streams should be monitored during periodic inspections for an increase in flow. A paved channel or half pipe sections should be provided to deter erosion from the flow from the wet area on the left abutment.

EMBANKMENT

VISUAL EXAMINATION OF		REMARKS OR RECOMMENDATIONS	
		OBSERVATIONS	
ANY NOTICEABLE SEEPAGE (CONTINUED)	A small stream runs down the left slope of the downstream valley approximately 50 feet from the toe. It disappears into the ground at about station 4+00. A wet area also exists on the downstream right abutment beginning at approximately station 1+50, extending 15 feet out from the toe and down the abutment to the outfall pipe.		(Station numbers refer to Field Sketch).
DRAINS	There are no known embankment drains.	None.	
MATERIALS	Area materials are low plastic sandy silts and sandy clays.	None.	
VEGETATION	The embankment is well vegetated with grass, except the riprapped area of the upstream face and the road traversing the crest. Sm' ll shrubs and saplings are scattered over the downstream face.		The shrubs and saplings should be cut off at ground level.

PRINCIPAL SPILLWAY

VISUAL EXAMINATION OF

OBSERVATIONS

REMARKS OR RECOMMENDATIONS

CONTROL SECTIONS

The control section is a concrete drop inlet located about 75 feet upstream of the embankment. Six 7.5-inch horizontal flashboards are located just below the crest of the spillway. Two of the high flashboards have been removed to allow flow through the spillway. A steel bar trash rack is located on top of the riser to protect the intake from large debris.

None.

DISCHARGE CHANNEL

A 30-inch concrete pipe outlets into a small stilling basin with a concrete slab as a splash block. Natural rock lines the downstream channel. A flow about 10-inches deep is passing through the pipe.

None.

EMERGENCY GATE

7.5-inch flashboards are placed in the drop inlet riser. To lower the reservoir, the boards must be removed one at a time. An 18-inch square gate, located at the base of the drop-inlet, can drain the reservoir to elevation 3576.2. The gate is operated by turning the valve stem located at the top of the concrete drop inlet.

Representative reports that the reservoir has been drained three times in the past 7 years.

EMERGENCY SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONTROL SECTIONS	The control section is located in natural ground at the right abutment. The ground is slightly irregular through the control section. Some natural rock is located throughout the area. A asphalt paved driveway connects the embankments to the control section.	None.
APPROACH CHANNEL	The approach channel is slightly sloped in natural ground. The area is covered with sparse vegetation.	None.
DISCHARGE CHANNEL	The discharge channel directs flows parallel to the downstream channel and drops sharply about 1,000 feet downstream of the control section. A large erosion gully, 8 - 14 feet deep, is located at the point where the flow drops about 50 feet in elevation.	None.

INSTRUMENTATION

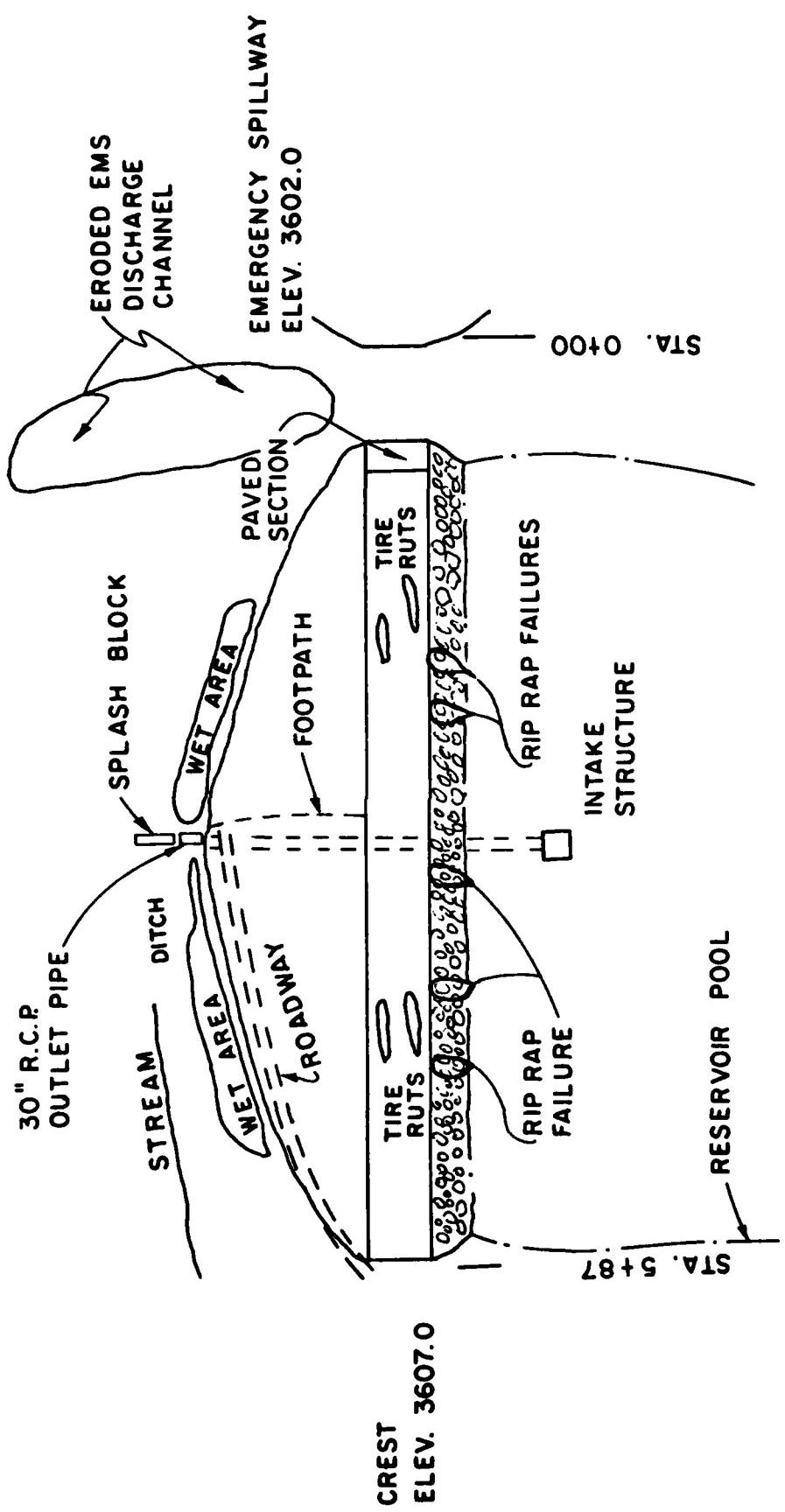
VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATION
MONUMENTATION/SURVEYS	There are no known monuments in the immediate area.	None.
OBSERVATION WELLS	There are no observation wells.	None.
WEIRS	There are no weirs.	None.
PIEZOMETERS	There are no piezometers.	None.
STAFFAGES	There are no staffgages.	A staffage should be installed in the reservoir to extend above the crest of the dam.

RESERVOIR

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	The reservoir slopes are mild to steep and heavily wooded. The watershed has no development or cleared areas. The lake is covered with a thick layer of ice, except around the shoreline. There is no evidence of shoreline erosion or reservoir slope failure.	None.
SEDIMENTATION	The inspection team is unable to evaluate the sedimentation condition.	None.

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF		OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)		The downstream channel is cluttered with large natural rock with some trees located near the stream. The channel drops rapidly in elevation, so there should be little problem of obstructed flows.	None.
SLOPES		The slopes are very steep and heavily wooded. Large natural rocks (boulders) are located around the area downstream of the dam.	None
APPROXIMATE NO. OF HOMES AND POPULATION		Structures are located along the stream about 4 -5 miles downstream of the dam. Because of the steep drop of the streambed, the flows during a dam failure should provide a destructive force until the flood plain widens and the slope decreases.	None.



PLAN VIEW OF THE DAM

NOT TO SCALE

1. SKETCH MADE FROM FIELD NOTES
2. ELEVATIONS FROM DESIGN DRAWINGS
(SEE PLATE I)

FIELD SKETCH

HIDDEN VALLEY LAKE DAM

WASHINGTON COUNTY

25 FEBRUARY 1981

APPENDIX IV
PREVIOUS INSPECTION REPORT



FROEHLING & ROBERTSON, INC.
INSPECTION ENGINEERS • CHEMISTS • BACTERIOLOGISTS
CABLE ADDRESS—"FROEHLING"

MAIN OFFICE AND LABORATORIES
P. O. BOX 8252, 101 EAST EAST STREET
RICHMOND, VIRGINIA 23225
PHONE 223-2202
BRANCH LABORATORIES
NORFOLK, CHARLOTTE, BALTIMORE,
WASHINGTON, BALTIMORE,
GREENVILLE, ROANOKE, PATRIOTVILLE,
BENNETTVILLE

Richmond, Virginia
June 30, 1972

Commonwealth of Virginia
Commission of Game and Inland Fisheries
P. O. Box 11104
Richmond, Virginia 23230

Ref: Inspection of Hidden Valley Dam
F&R Report #X-2000-6

Attn: Mr. Jack Hoffman

Gentlemen:

Upon authorization of Mr. Jack Hoffman of Commission of Game & Inland Fisheries, the writer visited the Hidden Valley Lake for the purpose of inspecting the dam. This visual inspection was aimed at determining the general dam conditions, presence of piping, leakage through the dam and around the primary spillway, condition of primary and emergency spillway and abutments and any other conditions pertinent to the function and safety of the structure. This report is of necessity general and limited to a visual inspection, review of available drawings and information, and knowledge of the geological history of the area. This general inspection does not however guarantee the integrity of the dam.

PAST HISTORY & DESIGN INFORMATION

It is not known when the original dam was constructed but according to drawings dated October 1, 1962 the dam was widened to a certain degree and heightened several feet at which time existing 24" diameter pipe primary spillway pipe and the tower structure were removed and replaced with a new header tower and a 30" diameter concrete spillway pipe running under the dam. The new tower structure was extended approximately 30 feet upstream from the old structure. Rip rap was to be placed on the upstream slope from elevation 3600.5 to 3604.5.

As is shown on drawings dated February 7, 1964 a shear crack was present in the section of pipe that joined to the primary spillway tower. This header tower, according to plans, was supported on a slab with steel rods grouted 4' into rock. A steel collar was to be put inside the cracked section of the pipe and expanded outward as well as being filled presumably with grout or sealant. Field stones set in mortar were placed on top of the drainage pipe. We have no knowledge as to whether the insuing construction of the dam or tower and pipe structure was carried out according to plan except it is evident that the sleeve was inserted into the pipe.

INSPECTION & OBSERVATIONS

The writer visited Hidden Valley Lake on April 6, 1972 and again in the presence of Mr. William J. Davis on June 16, 1972. On the first visit the lake was dry and the dam seemed to be, generally, in good condition. The upstream face of the dam had been washed to some slight degree by wave action. This condition could be corrected by the utilization of a graded rip-rap along the water line to dissipate the force of the waves. A slight depression approximately 40 feet from the tower section along the pipe was noted also. Seepage through the dam was noted around the bottom 1/3 of the downstream (toe) face of the dam. This seepage appeared slight and would be normal for this type

AMERICAN SOCIETY FOR TESTING MATERIALS • AMERICAN CERAMIC INSTITUTE • AMERICAN COUNCIL OF INDUSTRIAL LABORATORIES • VIRGINIA ACADEMY OF SCIENCE • VIRGINIA STATE SCIENCE ACADEMY • SOUTHERN ASSOCIATION FOR STANDARDS & INSPECTION • SOCIETY FOR TEST METHODS IN TESTING & INSPECTION • CHAMBER OF COMMERCE
REPRESENTATIVE OF AMERICAN WATER WORKS ASSOCIATION • ASSOCIATION OF WATER POLLUTION TECHNOLOGISTS • AMERICAN WATER WORKS ASSOCIATION • AMERICAN STANDARDS ASSOCIATION • AMERICAN PUBLIC HEALTH ASSOCIATION • PETROLEUM INSTITUTE • AMERICAN PAPER INDUSTRY • VIRGINIA POWER & LIGHT COMPANY • VIRGINIA WATER POLLUTION CONTROL ASSOCIATION • AMERICAN WELDING SOCIETY • AMERICAN SOCIETY OF CIVIL ENGINEERS • SOCIETY OF AMERICAN CONCRETE INGENIERS

June 30, 1972

of earthfill dam.

A road had been cut lengthwise along the downstream face of the dam. This road could provide an avenue for water flow and therefore provides erosion potential. This road should be filled in and the degree of slope of the dam be maintained. After correcting the slope the area should be planted to further guard against erosion.

A muskrat or groundhog hole was noted along the primary spillway outlet pipe. This hole was at least 9 feet deep and should be filled in before any problems could arise. Other than this hole the outlet pipe seemed to be in good condition.

The emergency spillway was along the right (southeast) abutment. The abutments to the dam seemed sound and the area was mainly rock outcropping indicating solid rock. This emergency spillway seemed to "bottom" on rock outcroppings which were present up the hill on the southeast side of the dam. A strip of paving about 8 feet wide and probably 50 feet long ran down the dam onto the spillway.

The emergency spillway is designed to carry the water approximately one hundred yards northeast and dump it into a small stream. A dike runs the length of the spillway to protect the downstream face of the dam from the water which could run over the emergency spillway. We feel that the face of this dike should be protected from erosion or scour by an asphalt or concrete lining at least 50 feet down the dike from the downstream face of the dam.

On June 16, 1972, the writer accompanied by Mr. William J. Davis, again visited the site. Ten feet of water was allowed to collect in the dam so that any leaks present could hopefully be found. A small volume of water ran out the downstream pipe indicating a leak around or in the primary spillway pipe. On checking the primary spillway pipe from inside the header structure, leakage was discovered at the first joint where the pipe joins the tower structure. Leakage could also be occurring around the old crack but is probably slight. Another leak was observed approximately 40 feet back from the header structure to the downstream side in the pipe joint. This probably accounts for the conical shaped depression observed in the upstream face of the dam when it was drained. The distance from the header structure for the observed leak and the depression were approximately the same.

Although with ten feet of water in the lake, the leaks are relatively minor, they will increase appreciably with additional head and over a period of time. We therefore recommend that the area of the pipe which is leaking be excavated and the leaks repaired. Since the lake is drained this will be a relatively simple and inexpensive operation.

CONCLUSION

In conclusion the dam seems to be in generally good condition. The leaks around the primary spillway should be fixed since they will only worsen and since the lake is presently drained and will offer easy excess to the spillway. The roadway across the downstream slope should be filled in consistent with the present dam slope and planted for erosion protection. It would be a good idea as mentioned to pave the dike around the emergency spillway back away from the dam face to guard against scour and erosion in event the spillway is used. Rip-rapping the upstream face of the dam at present would also be helpful but does not seem imperative at this time. We strongly recommend that periodical inspection of the dam be provided to insure continued safety and evaluate needed maintenance. These observations and conclusions are the visual observations incurred

in two trips to the site and are thereby limited.

If there are any questions or if we may be of further service, please contact our firm.

Very truly yours,

FROEHLING & ROBERTSON, INC.


J. S. Thornton, Jr.



FROEHLING & ROBERTSON, INC.
INSPECTION ENGINEERS • CHEMISTS • BACTERIOLOGISTS
CABLE ADDRESS—"FROEHLING"

MAIN OFFICE AND LABORATORIES
P. O. BOX 2222, 614 WEST CARY STREET
RICHMOND, VIRGINIA 23220
PHONE 622-2020
BRANCH LABORATORIES
ARLINGTON, PHILADELPHIA, BALTIMORE
WASHINGTON, BALTIMORE
GREENVILLE, CHANDLER, PAYSON, ARIZONA
ALBUQUERQUE

Richmond, Virginia
June 30, 1972

Commonwealth of Virginia
Commission of Game & Inland Fisheries
P. O. Box 11104
Richmond, Virginia 23230

Attn: Mr. Jack Hoffman

Ref: Addendum to Report for
Hidden Valley Dam
F&R Report #X-2000-6

Gentlemen:

Shown below is the Geology portion for the Hidden Valley Dam.

GEOLOGY

Hidden Valley Lake lies in Northern Washington County about three miles north of Moccasin Gap. The lake has been built on Brumley Creek which flows into the North Fork of the Holston River.

This part of the Ridge and Valley Province of Southwestern Virginia is underlain by Silurian clastic rocks, white, red, and gray shales, sandstones, and quartzites of the Clinch-Tuscarora and Clinton formations. These rocks should provide an adequate foundation for the dam provided that care has been taken to locate and remove soft spots which may result from weathering of shale layers.

Very truly yours,

FROEHLING & ROBERTSON, INC.

Wm. H. Vogelsang

W. H. Vogelsang, Director
Foundation Investigation

WHV/dw

APPENDIX V

REFERENCE

REFERENCES

1. Recommended Guidelines for Safety Inspection of Dams, Office of the Chief of Engineers, Department of the Army, Washington, D. C.
2. HEC-1DB Flood Hydrograph Package, (Hydrologic Engineering Center, U. S. Army Corps of Engineers, September 1978.)
3. "Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," Hydrometeorological Report No. 51, (U. S. Weather Bureau, June 1978).
4. "Rainfall Frequency Atlas of the Unites States", Technical Paper No. 40, (U.S. Weather Bureau, May 1961).
5. "Design of Small Dams", Technical Publication of United States Department of the Interior, Bureau of Reclamation, Second Edition, Revised Reprint, 1977.